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Flexible Technical Assistance Program • 17 Columbia Circle • Albany, NY 12203-6399

NYSERDA Energy Conservation Study

City of Kingston Wastewater Treatment Plant

Kingston, New York

April 2007

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Contents

List of Figures

List of Tables

Appendices

Executive Summary

The City of Kingston (City) is faced with several proposed mixed use developments comprised of residential and commercial facilities and the prospect of developing a long-term control plan (LTCP) for its combined sewer overflows. A potential objective for the City may be to maximize the hydraulic capacity of the wastewater treatment facility (WWTF). The object of this study, which is being performed under the New York State Energy Research and Development Authority (NYSERDA) Flexible Technical Assistance Program (FlexTech), is to evaluate the maximum hydraulic capacity of the WWTF, with minimal capital improvements, and to identify energy efficient settled sewage pumps to match the increased flows to the WWTF.

The maximum hydraulic capacity was determined by the development of a Visual Profile model of the WWTF, while maintaining a minimum of six inches of freeboard in all tanks and open channels and performing minimal capital improvements. A maximum flow of 13.6 million gallons per day (mgd) was identified based on this criterion and considering a wet weather operating scenario of operating the aeration basins in a step feed mode with all flow entering the last gate. The improvements required to sustain a maximum flow through the WWTF are as follows:

- Replace the effluent pipe from the grit chamber with an open channel to reduce the headloss.
- Increase the weir length of both the primary and secondary clarifiers.
- Raise the channel elevation of the ultraviolet (UV) disinfection system.

In order to effectively evaluate the replacement of the settled sewage pumps, a simple payback method could not be utilized for this study. This is a result of looking at increased flows over current conditions. Therefore it was determined to utilize a wire-to-water efficiency of the existing pumps and any pumps evaluated for this study.

Three alternatives were evaluated for this study. These alternatives as follows:

- Replace the existing pumps in kind, increasing the installed impeller size.
- Replace the existing pumps with three similar pumps by another manufacturer in a two duty, one standby configuration.
- Replace the existing pumps with two larger and one smaller pump in a two duty, one standby configuration.

Based on the finding contained herein, the best solution is to increase the size of the pump discharge piping and header from 12- and 14-inch to 18-inch diameter pipe. Reducing the friction headloss by increase the pipe size can increase the wire-to-water efficiency from a baseline condition of 6.35 gallons per watt-hour (gal/W/hr) to 10.07 gal/W/hr at average daily flows. This study outlines several pump options available to the City of Kingston, if the maximum capacity of the WWTF is increased to 13.6 mgd.

1. Introduction

1.1. Background Information

The City of Kingston Wastewater Treatment Facility (WWTF) operates under the New York State Pollution Discharge Elimination System (SPDES) Permit Number NY 002 9351. The WWTF, located on East Strand Street in the City of Kingston, currently treats combined sewage (consisting of domestic wastes, commercial wastes, storm water and some industrial wastes) from the City of Kingston and several neighboring municipalities. The City is currently in the plan review phase to accept sewage from three proposed mixed use developments (The Landing, Sailor's Cove, and the Parking Garage Redevelopment Projects). Electricity is purchased from the Central Hudson Gas & Electric Corporation (CHG&E).

The WWTF, as it currently exists, was upgraded in the early 1970s to treat sewage using a conventional activated sludge process. During that time, the WWTF was designed for an average flow of 4.8 million gallons per day (mgd) through the aeration and secondary clarification processes. Modifications to the WWTF included the addition of a fourth primary clarifier in the early 1980s and the construction of a third aeration tank and a fourth secondary clarifier in the early 1990s. The current SPDES permit limits the flow to 6.8 mgd based on a 12-month rolling average, which is advantageous to a community with combined sewers. The WWTF discharges to the Rondout Creek, a tributary to the Hudson River.

1.2. Purpose of Report

This study, which is being performed under the New York State Energy Research and Development Authority (NYSERDA) Flexible Technical Assistance Program (FlexTech), has three objectives. The first is to evaluate the energy efficiency associated with the Settled Sewage Pumps and identify potential improvements to reduce electrical power consumption and increase electrical efficiency. The second is to determine the existing hydraulic capacity of the WWTF. The third is to assess WWTF modifications to increase the hydraulic capacity, including to the Settled Sewage Pumps. Malcolm Pirnie, Inc. (Malcolm Pirnie) has been identified by the City and NYSERDA to complete the evaluation.

1.3. Scope of Work

The scope of work for this study includes the following tasks to improve energy and process efficiency:

- Evaluate the current hydraulic capacity of the WWTF;
- Evaluate Settled Sewage Pump replacement alternatives to reduce electrical consumption and increase capacity; and
- Estimate the capital costs and wire-to-water efficiency associated with the improvements.

The findings of this study are outlined herein.

2. Existing Equipment and Systems

2.1. Hydraulic Capacity

A Visual Profile model (proprietary hydraulic model developed by Malcolm Pirnie) of the WWTF was prepared to assist in determining its maximum wet weather hydraulic capacity. Based on a previous study of the WWTF completed by Malcolm Pirnie, the mode of operation was recommended to be changed with higher flows in the future from plug flow to step feed in order to assist in preventing solids from washing out during high flows and increasing the solids residence time (SRT) of the aeration process. The model developed included provisions to operate the WWTF in this step feed mode of operation. The criterion established to determine the maximum wet weather hydraulic capacity of each unit operation and open channel was maintaining a minimum of 6 inches of freeboard during peak flows. The Recommended Standards for Wastewater Facilities typically requires a minimum of 12 inches of freeboard for the design of new wastewater treatment facilities at peak flows; however, 6 inches of freeboard should provide sufficient margin of error in order to maximize the capacity of the existing WWTF.

Several operational modifications were incorporated into the hydraulic model, as described above, to reflect recommended changes that would increase the WWTF's organic treatment capacity. The following changes were incorporated into the model:

- The elevation of the aeration basins' effluent weirs was raised from approximately 13.5 feet to 15 feet to prevent the weirs from becoming submerged.
- The elevation of the secondary splitters' gates was raised from approximately 13 feet to 13.5 feet to increase control and increase the tank level in the aeration basins.
- The model was run to determine maximum hydraulic capacity through the WWTF using the following criteria:
- All primary clarification, aeration, and secondary clarification basins were in service.
- The weir lengths of the primary clarifiers are increased to 96 linear feet.
- Two of the three feed gates to each aeration basin were closed with only the third gate open. The third gate is the gate nearest to the effluent weir. The gate was opened to a depth of 2 feet as opposed to the usual operating condition of all three gates open approximately 3 inches.
- Weir lengths of the secondary clarifiers are increased to 96 linear feet.

- Two of the three ultraviolet (UV) disinfection channels were in service.
- A 25-year flood elevation of 7.7 feet was used for Rondout Creek based on Federal Emergency Management Agency (FEMA) data.

The flow through the plant was increased incrementally from its average of 5.4 mgd, or 3,750 gallons per minute (gpm), and the liquid level of each element was compared to the top of wall for each unit operation and open channel.

With the parameters described above in place, the hydraulic capacity of the WWTF was determined to be 10.25 mgd (7,118 gpm). The unit operation that approached the minimum 6 inches of freeboard was the grit chamber.

Table 2-1.
WWTF Wastewater Levels at Various Flow Rates

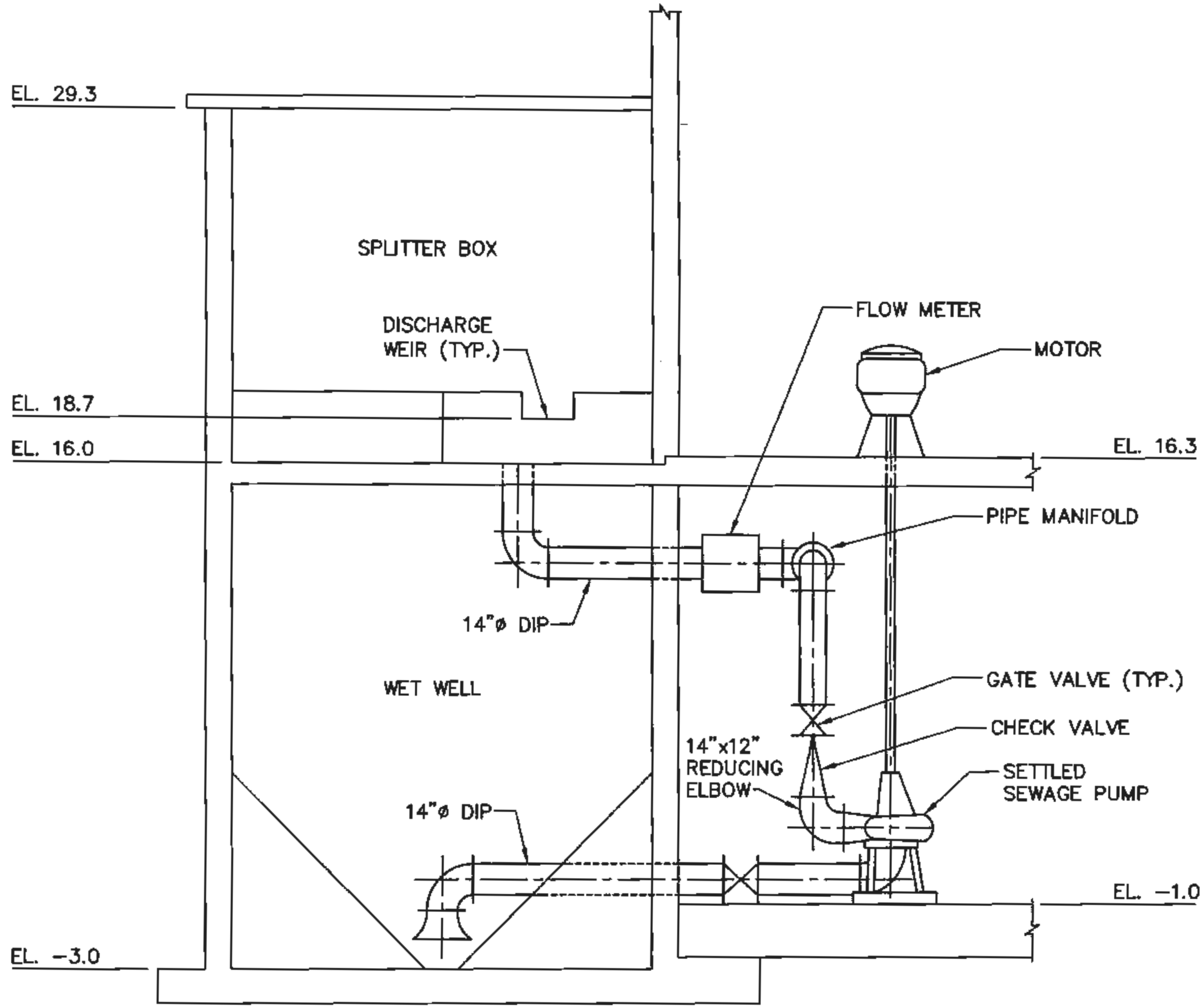
WWTF Location	WASTEWATER ELEVATION AT				Overflow Elevation (ft)
	5.4 mgd (ft)	10.25 mgd (ft)	11 mgd (ft)	13.6 mgd (ft)	
Entrance Channel	11.0	11.7	11.8	12.3	13.1
Grit Chamber	10.7	11.0	11.1	11.4	11.5
Primary Clarifiers	8.8	9.0	9.0	9.1	10.0
Aeration Tanks	15.2	15.3	15.4	16.0	16.5
Secondary Clarifiers	12.6	12.6	12.6	12.8	15.1
UV Area	8.1	9.3	9.5	10.4[1]	10.0

[1] Hypothetical elevation if the walls were infinitely high.

Based on the liquid level elevations presented in Table 2-1, the maximum wet weather capability of the WWTF is approximately 10.25 mgd. Please note that the existing settled sewage pumps were not included in this open channel gravity flow analysis and are discussed separately below.

2.2. Settled Sewage Pumps

The existing Settled Sewage Pumps are Allis-Chalmers (ITT-AC) Model 14x14x17.5 pumps with 890 rpm, 50-hp motors. There are three Settled Sewage Pumps (Pumps 1, 2, and 3) located in a pump room adjacent to the Primary Settled Sewage Wet Well (Wet Well). The pumps each draw from near the base of the Wet Well with dedicated 14-inch suction lines. The pumps discharge to a header that fills a splitter box located above the wet well. Each pump has a gate valve on its suction and discharge piping as well as a check valve on the discharge piping, see Figure 2-1. The seals on Pump 1 leak excessively, such that the pump is only used during extremely high flows. The sump pump in the pump room cannot keep up with liquids leaking from the seals of Pump 1. Pump 2 also leaks at its seal, though not as excessively as Pump 1. Pump 3 is the only pump that appears to be operating within its design parameters.



MALCOLM PIRNIE

CITY OF KINGSTON
KINGSTON, NEW YORK
EAST STRAND WWTF

EXISTING SETTLED SEWAGE PUMPS
SECTION SCHEMATIC (TYP. OF 3)
NOT TO SCALE

MALCOLM PIRNIE, INC.

APRIL 2007

FIGURE 2-1

To determine a wire-to-water efficiency at the WWTF's average daily flow of 5.4 mgd, it is necessary to determine the pumps' efficiency at this flow. The Settled Sewage Pumps have undergone multiple modifications since their installation more than thirty years ago, including motor and impeller changes and the addition of variable frequency drives (VFDs). Documentation of these changes has not always been complete. For example, the pumps were originally installed with 16.5-inch impellers, but it is believed that the impellers were trimmed to a diameter of approximately 14.62 inches, although verifiable written documentation is not available. These details are vital when attempting to determine the correlation between the system head curve (as presented in Figure 2-2) and the pump performance curve; however, actual performance data from Pump 3 was utilized for this report.

The system operating curve for the Settled Sewage Pumps was determined by estimating head loss through pipes, valves, and fittings and calculating a head for various flow rates. Since the condition of the pipes is unknown, a range of common Hazen-Williams friction coefficients (90 to 110) were used along with various wet well liquid levels to determine approximate existing operating conditions.

Based on the best available information, a 14.62-inch impeller was assumed for each of the three pumps and a motor with a maximum speed of 890 rpm was assumed. Using this information, a pump curve was obtained from the manufacturer, ITT (Figure 2-3). By correlating the two curves it can be estimated that the existing pump is 78 percent efficient at the average daily flow of 5.4 mgd.

With a known flow of 3,750 gpm at a head of 25.5 feet, 78 percent pump efficiency, and assuming a motor efficiency of 90 percent, the input horsepower to the pump is calculated as approximately 34.4 hp.

$$\frac{(3750\,gpm)\,x\,(25.5\,feet)}{3960\,x\,90\%\,x\,78.5\%} = 34.4\,hp$$

This equates to 25.7 kilowatts per hour (kWh) energy usage.

$$34.4HP\,x\,0.746 = 25.7\,kWh$$

Assuming the average flow of 3,750 gpm each day for a year, a pump would operate for 8,760 hours and pump 1,971 million gallons of settled sewage. Using 25.7 kWh the pump would use 224,793 kWh per year. This information is used to determine the wire-

FIGURE 2-2 Pump #3

Settled Sewage Pumps Existing System Curve

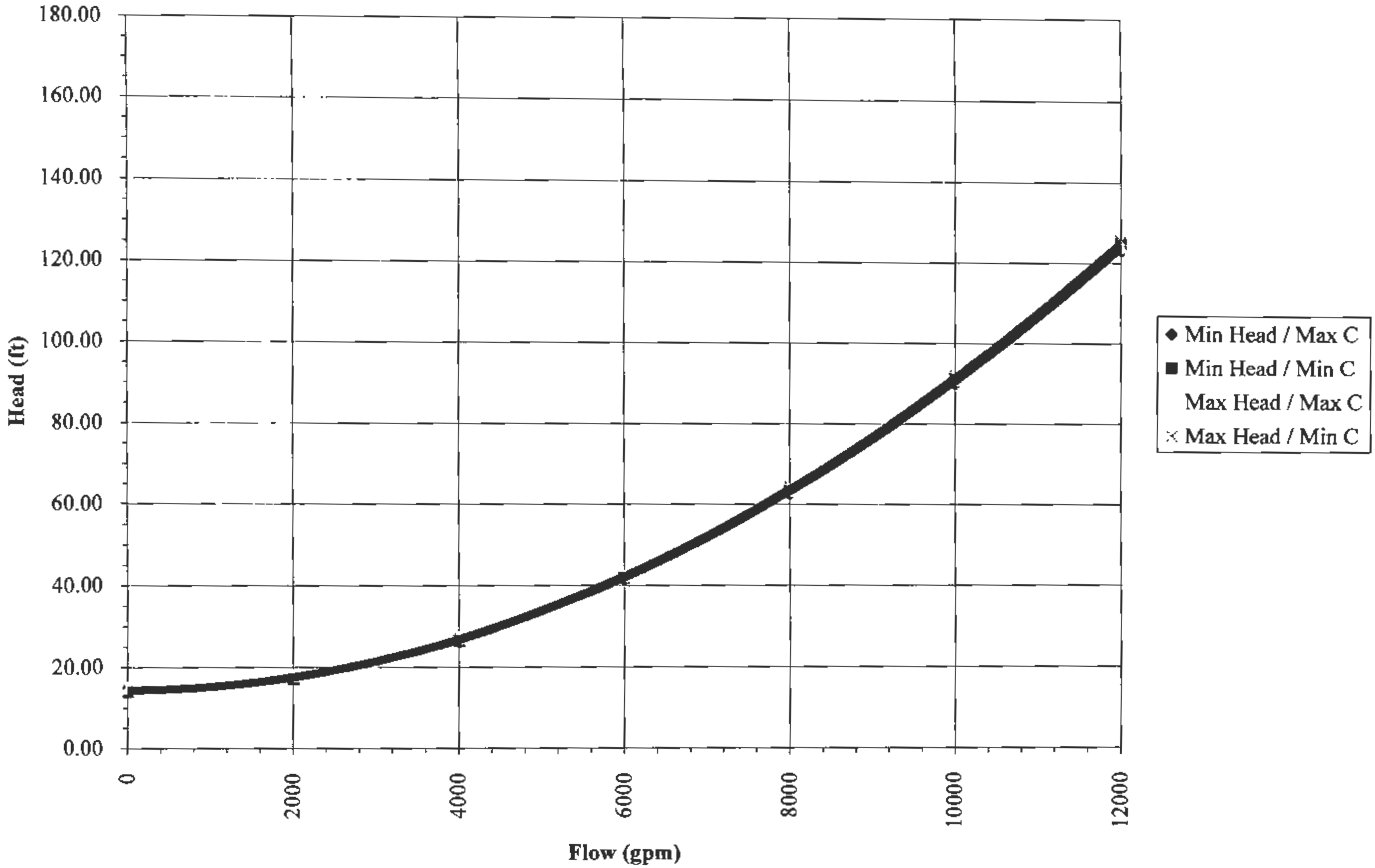
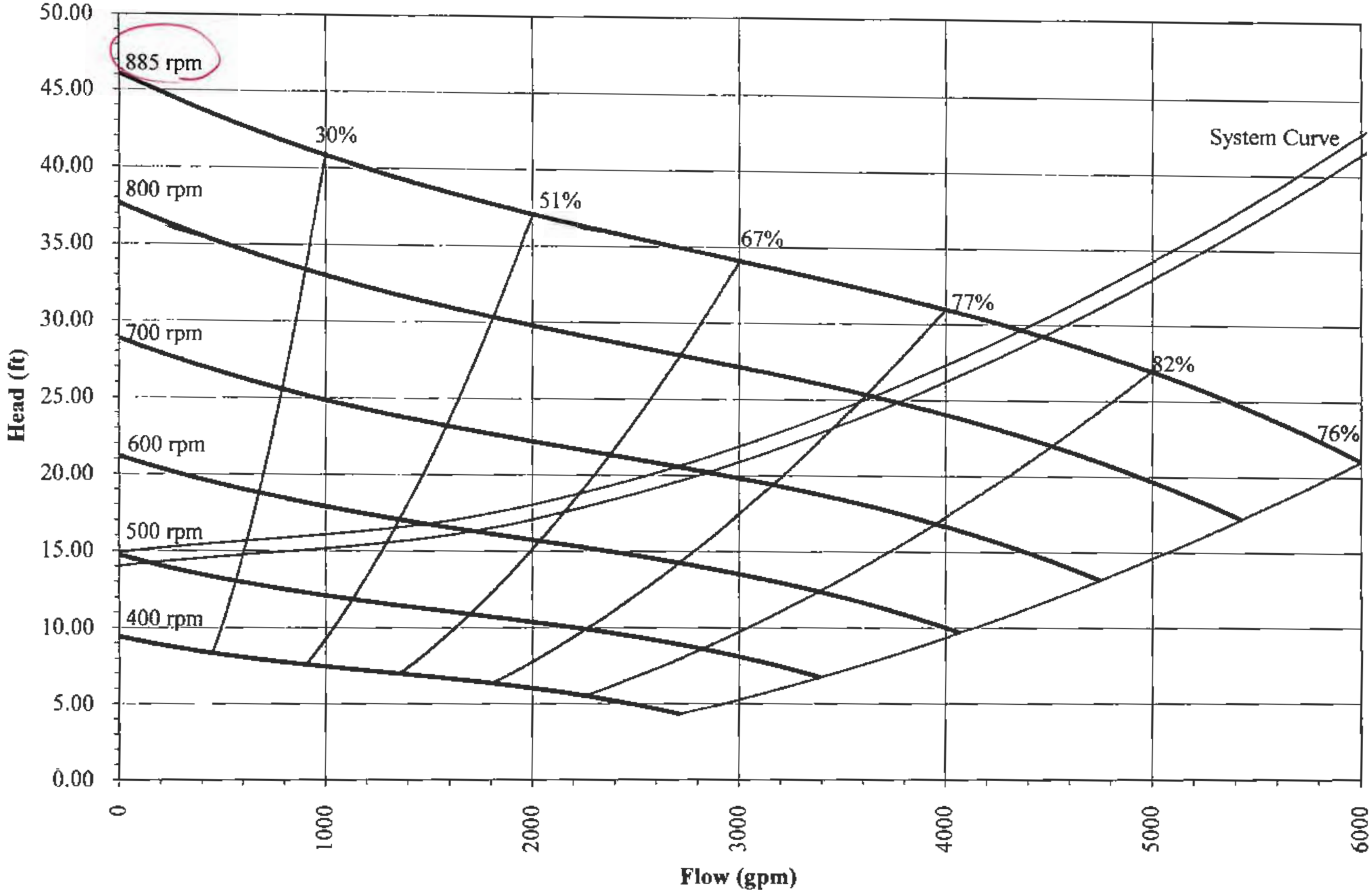


FIGURE 2-3 14.62-INCH IMPELLER (890RPM)

Settled Sewage Pumps Existing Pump and Head Curve



to-water efficiency of the pump, which provides a simple value to be used in comparing the relative energy efficiency of different options. The wire-to-water efficiency is expressed as the number of gallons the pump can handle per Watt used per hour (gal/W/hr).

$$\frac{1{,}971{,}000{,}000\, gal / yr}{224{,}793\, kW - hr / yr} = 8.77\, gal / W / hr$$

The estimated value of 8.77 gal/W/hr applies to Pump 3, but the wire-to-water efficiency of Pumps 1 and 2 would be expected to be lower due to their leaking seals. Therefore, 8.77 gal/W/hr should be considered the maximum wire-to-water efficiency achievable with the existing pumps as they are currently configured, but the actual performance of the three pumps as a whole will be lower due to the unmetered losses.

3. Alternative Systems Evaluation

3.1. Hydraulic Capacity

The City of Kingston would like to increase the maximum wet weather capacity of the WWTF to 13.6 mgd (9,444 gpm). Based on the hydraulic model, there are four modifications required for the WWTF to achieve this capacity. Two structural changes as well as two possible clarifier modifications are discussed below, not including modifying the Settled Sewage Pumps. The Settled Sewage Pump modifications are discussed in Section 3.2.

As stated in Section 2, the current hydraulic capacity of the WWTF approximately 10.25 mgd. Any increase in flow above 10.25 mgd reduces the desired freeboard in several unit operations.

3.1.1. Grit Chamber Modification

The first change is a modification to the grit chamber discharge. The grit chamber currently discharges over a weir to a collection channel. The collection channel discharges at one end to a 24-inch pipe which carries the wastewater approximately 8 feet, delivering it to a channel in the building housing the second automatic bar screen. The headloss associated with the wastewater entering, traveling through, and leaving this pipe is the key point of constriction which causes flows above 10.25 mgd to result in unacceptably high grit chamber liquid levels.

Several changes were evaluated to determine whether or not a major structural change was required. Constant cleaning of the three bar screens, resulting in zero blockage, had no effect on the grit chamber elevations. Small changes to the grit effluent collector box, such as widening it, did not prove sufficiently beneficial.

To alleviate this constriction, the 24-inch pipe should be replaced. It is proposed that the 3-foot wide channel that feeds the second bar screen be extended to the grit chamber. Wastewater would exit the grit chamber over the weir and enter the collection channel. From the channel the wastewater would drop into the extended channel and proceed to the bar screen and then the primary clarification tanks.

The hydraulic model developed to evaluate the hydraulic capacity of the WWTF was then modified as if the 24-inch pipe was removed and the drop and channel were installed as described above. With these changes in place the grit chamber is expected to be able to handle a flow of 13.6 mgd with approximately 6 inches of freeboard. Even with these modifications in place the grit chamber remains the key point of constriction for the front half of the WWTF with the feed channels and primary clarification basins capable of handling higher flows with adequate freeboard.

3.1.2. Primary Clarifiers

The surface overflow rate and the weir loading rates for the primary clarifiers is 2,475 gallons per day per square foot (gpd/sf) and 44,700 gallons per day per linear foot (gpd/lf) of weir, respectively at the peak hydraulic rate of 13.6 mgd. These rates are greater than the Recommended Standards for Wastewater Facilities. However, hydraulically, the WWTF will be able to handle the flows without overflowing the primary clarifiers. Consideration should be given to increasing the weir length by adding one more trough, which would decrease the weir loading rate to approximately 35,400 gpd/lf.

3.1.3. Aeration Tanks

Primary settled sewage flows to the settled sewage wet well by gravity. The three Settled Sewage Pumps lift the flow from the wet well via 12- and 14-inch pipes to a splitter box located above the wet well. From the splitter box the settled sewage then flows by gravity through the three aeration tanks and the remainder of the WWTF. Under all flow conditions modeled, the mixed liquor level remains below the minimum 6 inches of freeboard.

3.1.4. Secondary Clarifiers

The surface overflow rate and weir loading rates for the secondary clarifiers is 1,575 gpd/sf and 70,830 gpd/lf, respectively at the peak hydraulic rate of 13.6 mgd. The rates are greater than the Recommended Standards for Wastewater Facilities. However, hydraulically, the WWTF will be able to handle the flows without overflowing the secondary clarifiers. Consideration should be given to increasing the weir length by adding one more trough, which would decrease the weir loading rate to approximately 35,400 gpd/lf and the provision of chemical addition to add polymer to assist in settling during high flow wet weather events.

3.1.5. UV Treatment Area

Following secondary clarification, wastewater is directed to the UV treatment area adjacent to the primary clarification tanks. Flow is carried to the UV feed channel by a single 30-inch pipe. From the feed channel, flow can enter three channels in which UV disinfection units are installed. Unlike the other treatment elements, the hydraulic model assumes only two of the three channels (and their UV units) are in service for the purpose of providing redundancy, as required by the Recommended Standards for Wastewater Facilities.

At 11 mgd the wastewater level in the feed channel is approximately 6 inches from the top of the concrete walls. There are no operational changes that can be made to prevent overflow of the UV area at flows above 13 mgd. The main reason is that the period being evaluated is a 25-year flood with a discharge stream elevation of 7.7 feet. The top of the UV channel walls are only at elevation 10 and there is significant headloss through the discharge pipes. To account for maximum flow of 13.6 mgd, during 25-year floods, the UV channels should be raised at least 18 inches to prevent overflows in the future.

One additional item was incorporated into the hydraulic model. The City of Kingston is currently planning to remove the UV disinfection equipment from two of the UV channels and replace it with new equipment. Assumptions provided by the City were used in finalizing the model. These assumptions were:

1. The headloss provided for one of the proposed units was used to represent the headloss in the model for each of the units.
2. The new units require a narrower channel. The proposed channel contractions and subsequent expansions, as shown on the preliminary drawings supplied to Malcolm Pirnie, were included in the model.

After these changes were incorporated the model was run at a flow of 13.6 mgd to determine how much the wall height must be increased in the UV area to prevent overtopping and provide at least 6 inches of freeboard. At 13.6 mgd the liquid level in the UV feed channel reaches 10.7 feet, which is approximately 8-1/2 inches above the top of the channel.

To provide adequate freeboard at 13.6 mgd during a 25-year flood, the UV area's concrete should be raised at least 18 inches to provide sufficient freeboard at the maximum flows. The UV equipment must also be raised with the walls and the canopy.

3.2. Settled Sewage Pumps

The City of Kingston has several options available for reducing the electrical consumption and increasing the capacity associated with the Settled Sewage Pumps at the WWTF. These options are as follows:

- **Alternative 1:** Replace the three existing pumps in kind with 15.125-inch impellers and utilize the existing motors and VFDs. Reduce the total head by replacing the existing 12- and 14-inch discharge piping with 18-inch diameter piping. The pumps would operate in a 2 continuous duty, 1 standby configuration to pump a maximum of 13.6 mgd.
- **Alternative 2:** Replace the three existing pumps with three pumps, as manufactured by Patterson, and utilize the existing motors and VFDs. Reduce the total head by replacing the existing 12- and 14-inch diameter discharge piping with 18-inch diameter piping. The pumps would operate in a 2 continuous duty, 1 standby configuration to pump a maximum of 13.6 mgd.

- **Alternative 3:** Install two high-capacity pumps and one jockey pump. One high-capacity pump operating with the jockey pump would be capable of pumping 13.6 mgd. During periods of low flow the jockey pump would be the only active pump. The existing motors and VFDs would have to be replaced and the existing 12- and 14-inch diameter discharge piping would be replaced with 18-inch diameter piping.

Additionally, the City of Kingston has the option of upgrading the existing pumps without making significant modifications to the pump discharge piping. This option is the baseline condition to which the three Alternatives listed above were compared in order to determine a simple payback period for construction costs based on energy savings. Three identical pumps would be installed, with two pumps capable of pumping 13.6 mgd. In addition to the pumps, the motors and VFDs would have to be replaced along with electrical upgrades required to power the larger pumps.

Based on replacing the existing 12- and 14-inch discharge piping with 18-inch diameter piping, a projected system curve (Figure 3-1) was developed from the modified head data shown in Table 3-1.

Table 3-1.
Settled Sewage Pumps 18-Inch Piping System Curve Data

Flow (gpm)	Low Head (feet)	High Head (feet)
2,000	14.8	15.7
4,000	17.7	18.1
6,000	21.0	22.0
8,000	26.4	27.5
10,000	33.3	34.5
12,000	41.8	43.1

3.2.1. Alternative 1

The first alternative is to replace the existing pumps in kind. The replacements would have larger impellers, 15.125 inches, and would re-use the existing 50 hp, 900 rpm motors and VFDs. Recent test data supplied by the City of Kingston is summarized in Table 3-2 and shows a consistent pattern of performance by the three existing Settled Sewage Pumps. At most VFD settings, especially higher settings, Pump 3 produces more flow than Pump 2, which produces more than Pump 1. The generated flow is also pumped at a higher pressure by Pump 3. Clearly, Pump 3 is operating more efficiently than either of the other two pumps, which are wasting energy pumping water that is lost through faulty seals.

FIGURE 3-1
Settled Sewage Pumps Proposed System Curve

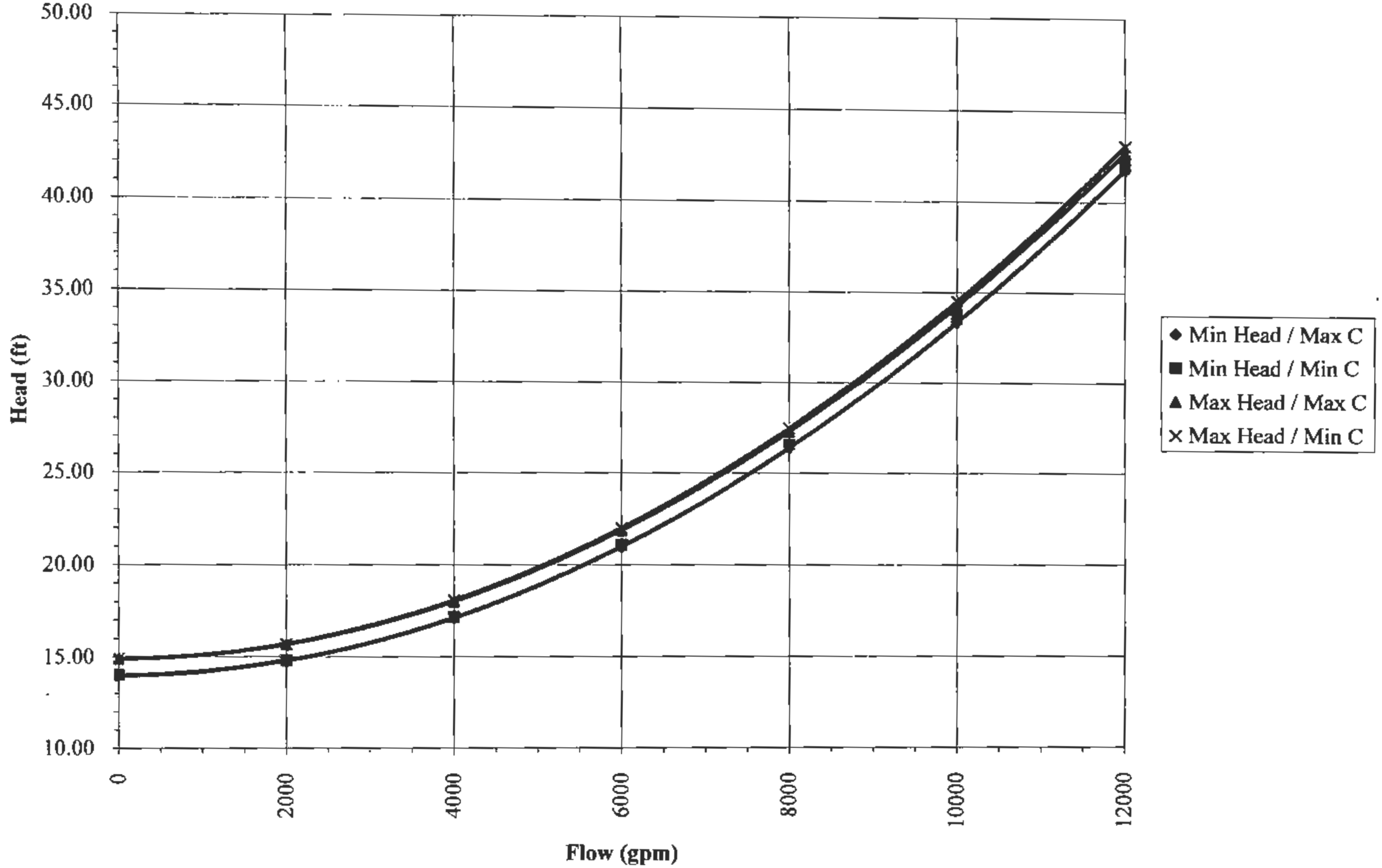


Table 3-2.
Settled Sewage Pump Tests - February 1, 2007

	Flow (mgd)			Discharge Pressure (psi)		
Speed	Pump 1	Pump 2	Pump 3	Pump 1	Pump 2	Pump 3
40 Hz	3.20	3.54	3.22	8	8	8
45 Hz	4.17	4.40	4.42	8	9	9
50 Hz	5.01	5.25	5.39	9	10	10
55 Hz	5.79	6.00	6.21	10	11	11
60 Hz	6.52	6.74	7.00	12	13	15

Source: City of Kingston

Replacement pumps with larger impellers would operate at approximately 81.5 percent efficiency at the future average daily flow of 6.48 mgd, and with the reduced head due to the larger piping the pumps will have the capacity to pump 13.6 mgd with only two pumps in service and meet the redundancy recommendations of the *Recommended Standards for Wastewater Facilities*.

Figure 3-2 shows the manufacturer pump curve for the replacement pumps, plotted with the modified system curve. Figure 3-3 shows the capacity of two pumps operating simultaneously. The wire-to-water efficiency of the upgraded pumps is estimated to be 10.25 gal/W/hr. vs/ 8.77 (pump #3) (7% eff incr.)

The estimated construction cost for Alternative 1 is $324,522 (see Appendix A).

3.2.2. Alternative 2

Alternative 2 includes the selection of three new pumps, which should also be able to re-use the existing 900 rpm motors and VFDs. A representative option is a Patterson Type F Sewage pump, model F12A, with a 15.875-inch impeller. The wire-to-water efficiency of the pump is an estimated 10.07 gal/W/hr at the future average daily flow. The pump curve and system curve are plotted together on Figure 3-4 and Figure 3-5 shows the capacity of two pumps operating simultaneously.

According to the manufacturer, the Patterson pumps should be able to operate at the WWTF minimum flow of 1 mgd for short periods, such as overnight during low flow periods, without adverse impact on the pump.

The estimated construction cost for Alternative 2 is $297,378 (see Appendix B).

3.2.3. Alternative 3

Alternative 3 is a slight variation of Alternative 2. In an attempt to locate a pump that would operate at a better efficiency at the WWTF average flow of 5.4 mgd and minimum

FIGURE 3-2
Alternative 1 Pump and System Curve - Single Pump Operation

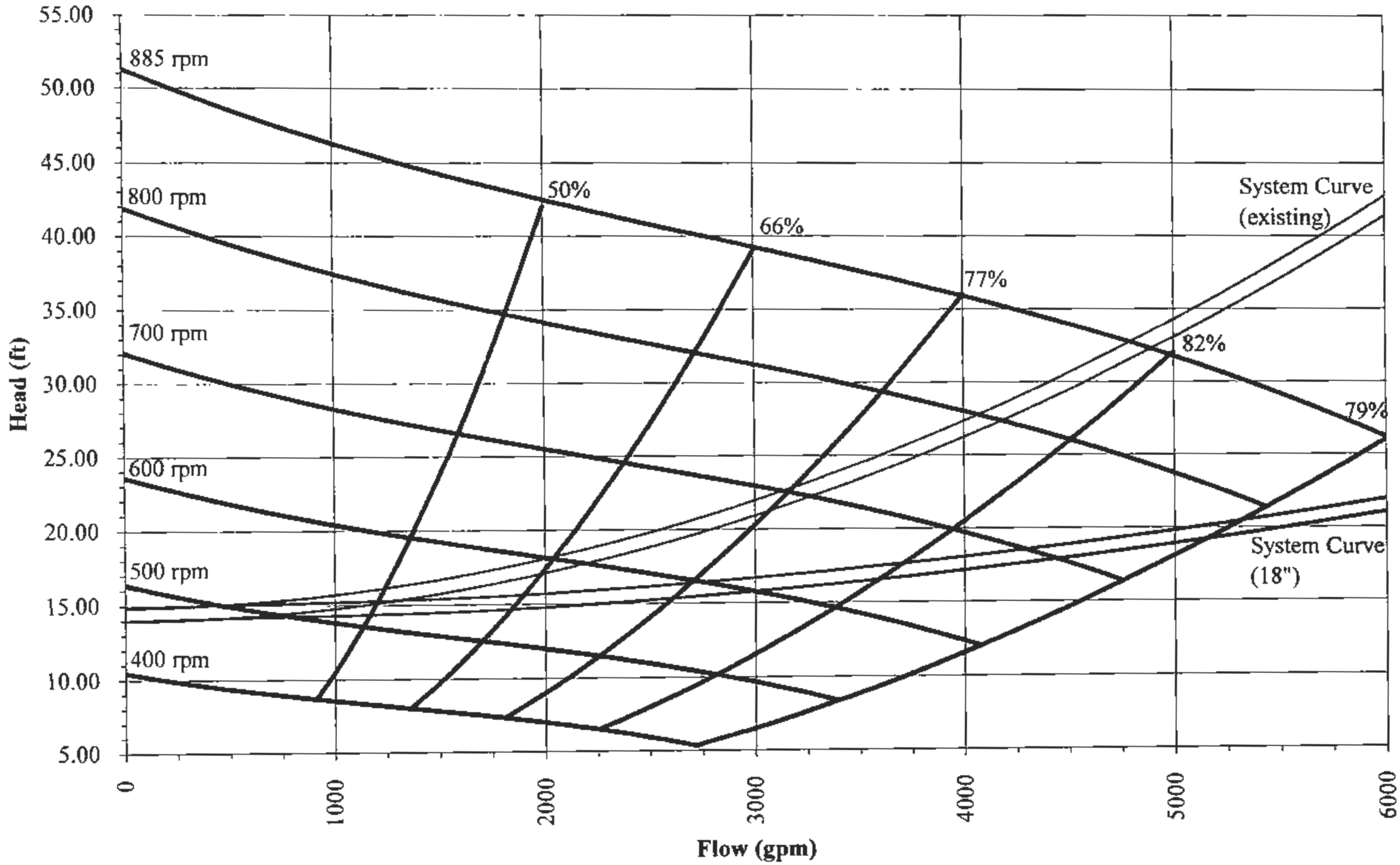


FIGURE 3-3
Alternative 1 Pump and System Curve - Two Pump Operation

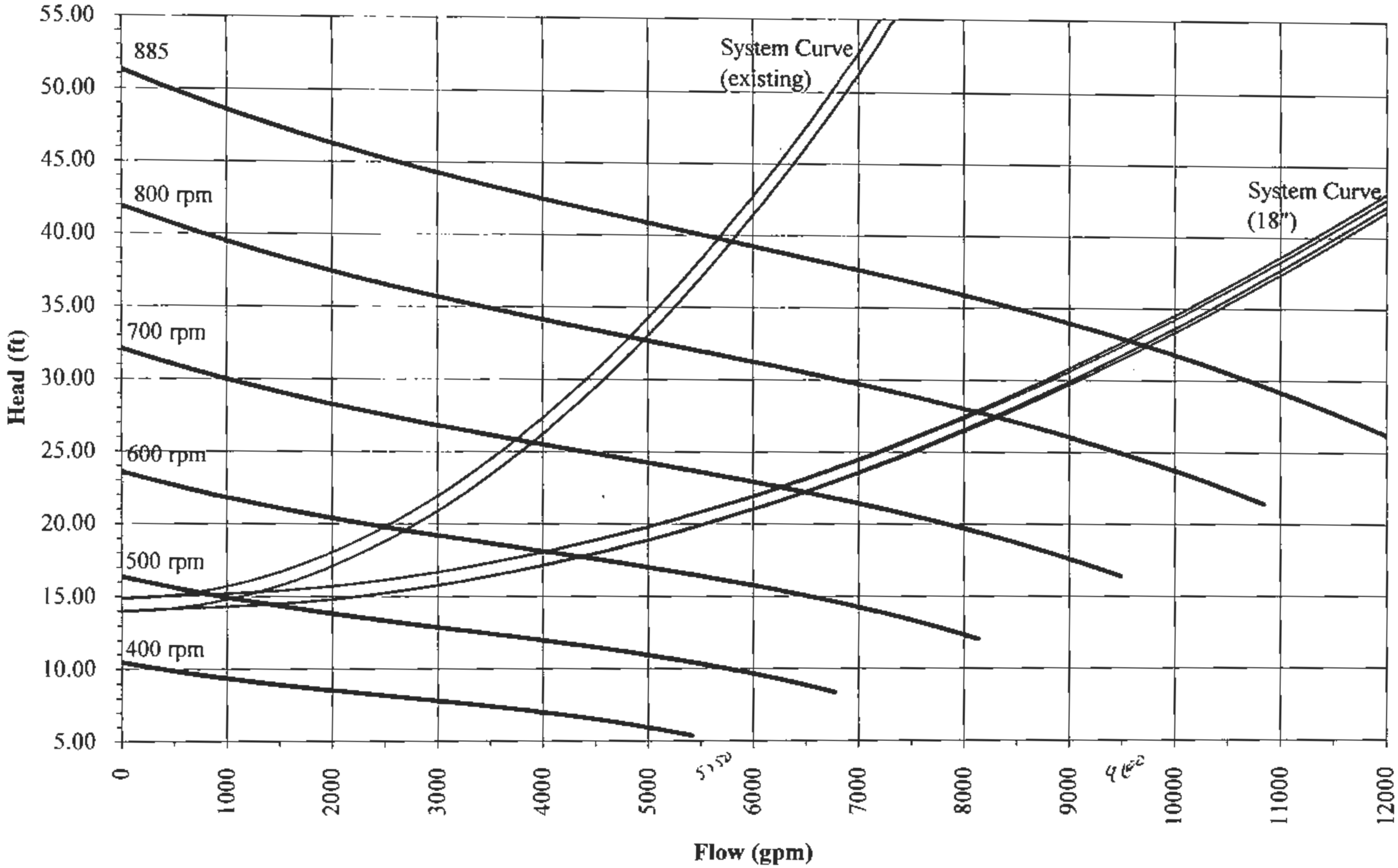


FIGURE 3-4
Alternative 2 Pump and System Curve - One Pump Operation

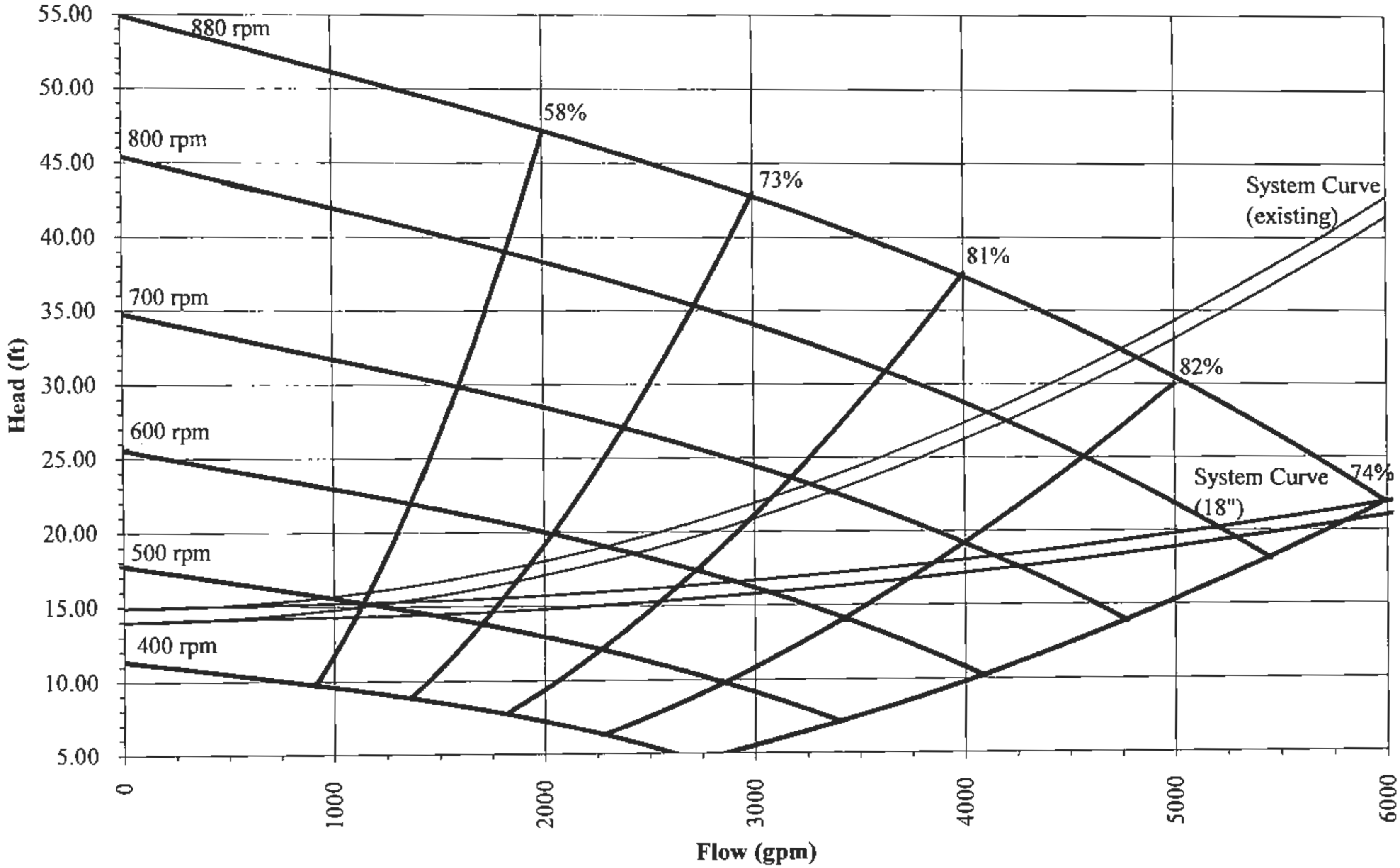
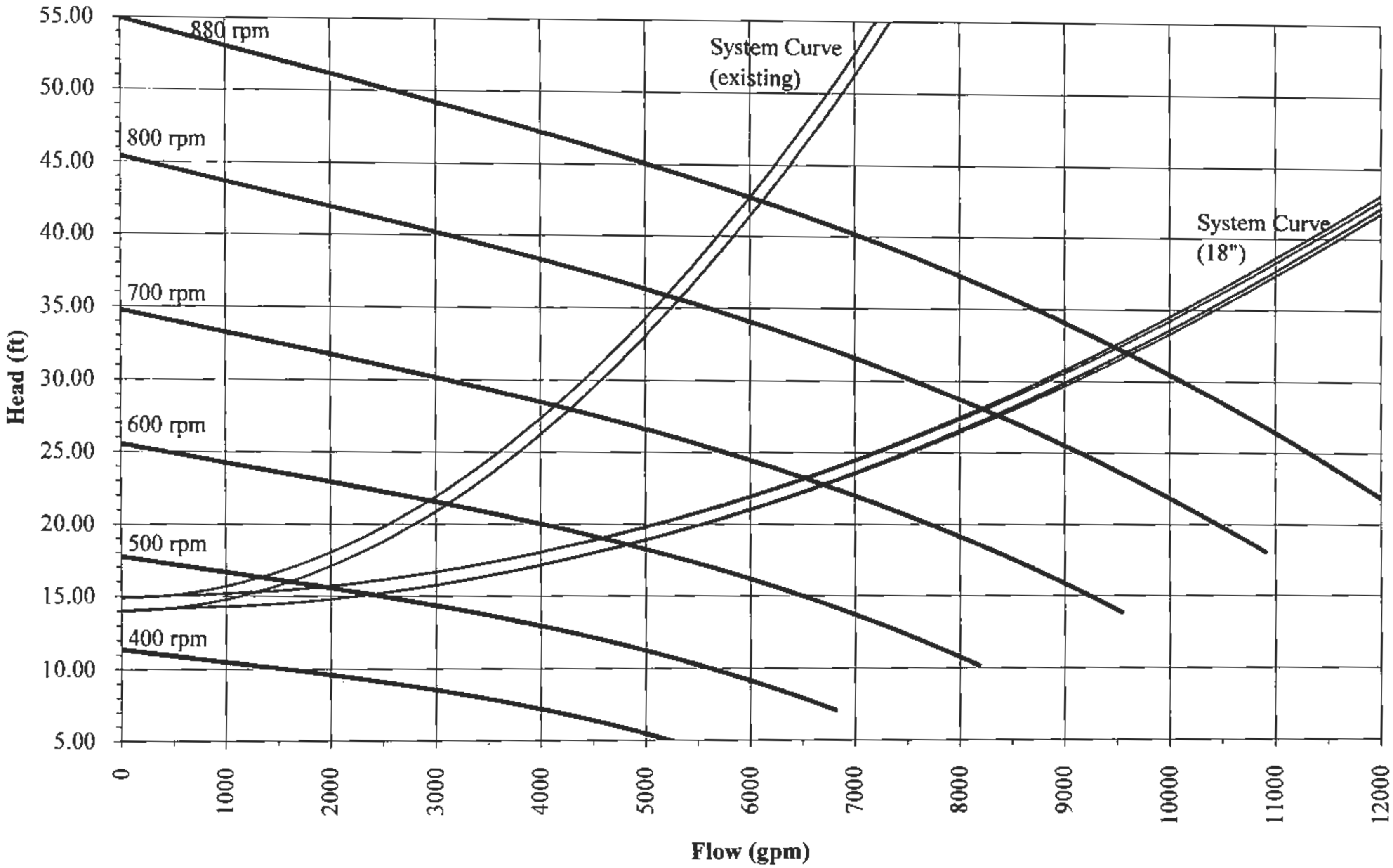


FIGURE 3-5
Alternative 2 Pump and System Curve - Two Pump Operation



flows, the possibility of installing two high-capacity pumps with a single lower-capacity jockey pump was evaluated. Under this scenario the jockey pump would combine with one of the large pumps to meet peak flow demands.

Patterson Pump models were located that provided representative possibilities. The high-capacity pumps would be model F16B Type F Sewage pumps with 19-inch impellers and 75 hp motors operating at a maximum of 705 rpm. The jockey pump would be a Type F Sewage pump model F12A with a 17.9375-inch impeller and 50 hp motor operating at a maximum of 705 rpm. The pumps would require new motors and VFDs, including the jockey pump. At average conditions the jockey pump would be operating at approximately 585 rpm and the manufacturer considers a 900 rpm motor unacceptable for the jockey pump's range of operation. Under this Alternative, future average day *pumping* would be handled solely by the jockey pump with a wire-to-water efficiency of 10.33 gal/W/hr.

Pump curves plotted against the system curve can be seen in Figures 3-6 and 3-7 and a combined pump curve is shown in Figure 3-8.

The estimated construction cost for Alternative 3 is $455,922 (see Appendix C).

3.2.4. Baseline Condition

If the City were to replace the existing pumps with pumps that were capable of pumping 13.6 mgd without replacing the existing discharge piping, the peak head requirement would be approximately 83 feet (refer to Figure 2-2). This would result in a maximum brake horsepower requirement of approximately 124 hp. The variable frequency drives, motors, emergency generator, motor control center (MCC), and the electrical service would need to be replaced in order to accommodate the new pumps.

A Patterson model 14x12x21.5 pump would be capable of providing the required flow at the peak head. The pump would be equipped with a 150 hp, 900 rpm motor and a 20.625-inch impeller. Future average daily flow pumping would be accomplished by one pump with an estimated wire-to-water efficiency of 6.35 gal/W/hr.

The estimated construction cost for the baseline condition, not including electrical upgrades to the MCC, emergency generator, or service supply, is approximately $285,120 (see Appendix D).

FIGURE 3-6
Alternative 3 Pump and System Curve - Jockey Pump

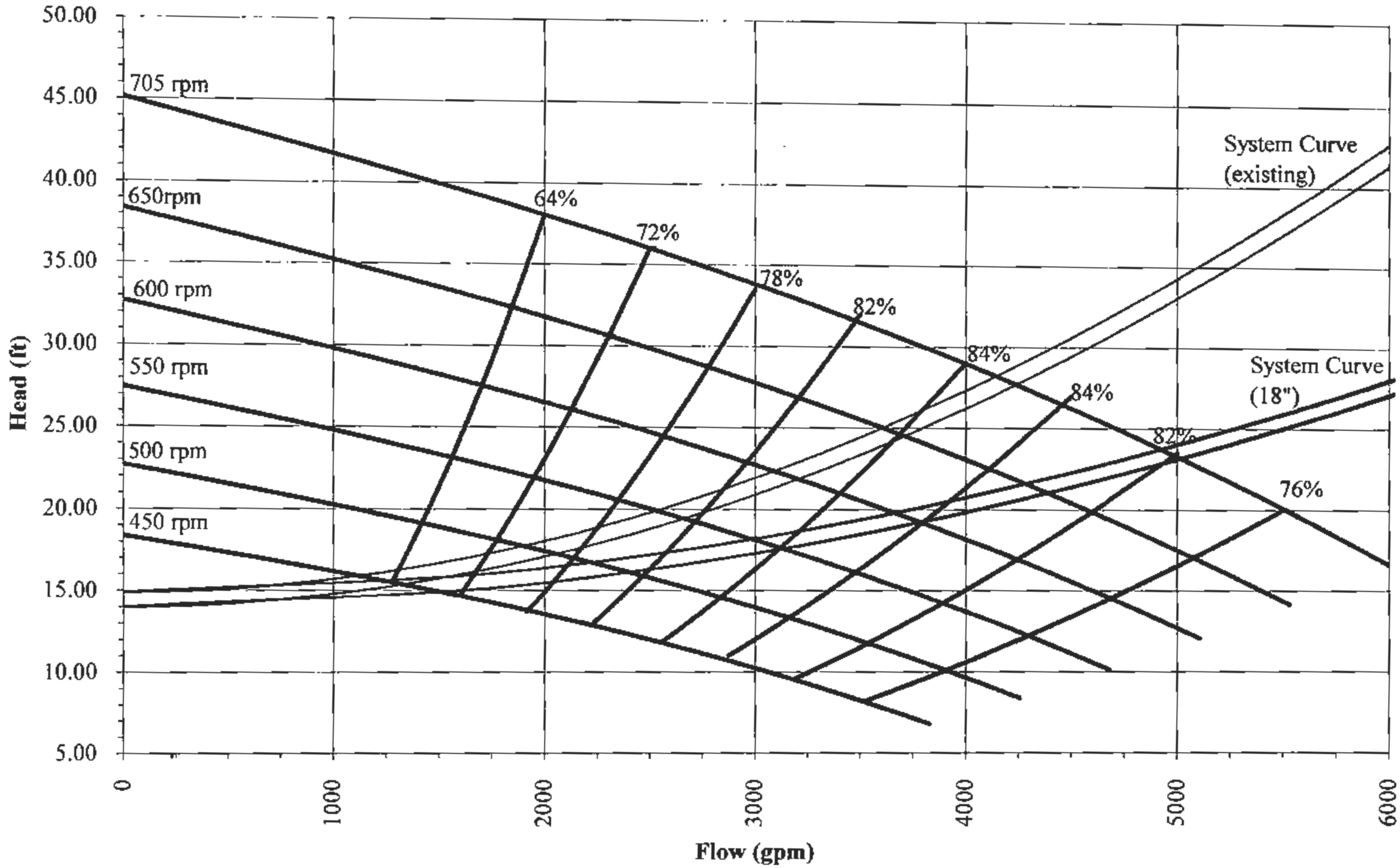


FIGURE 3-7
Alternative 3 Pump and System Curve - High Capacity Pump

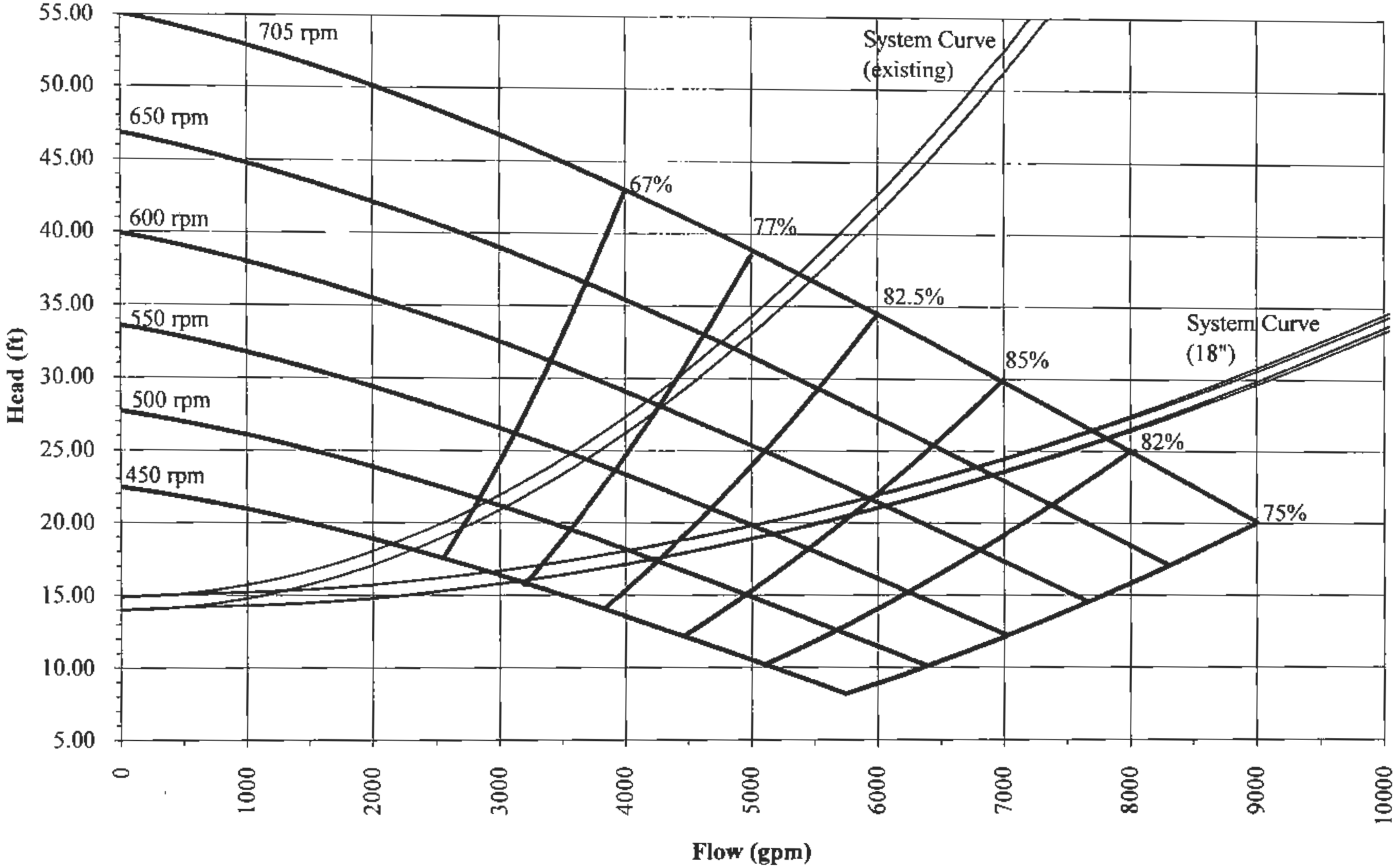
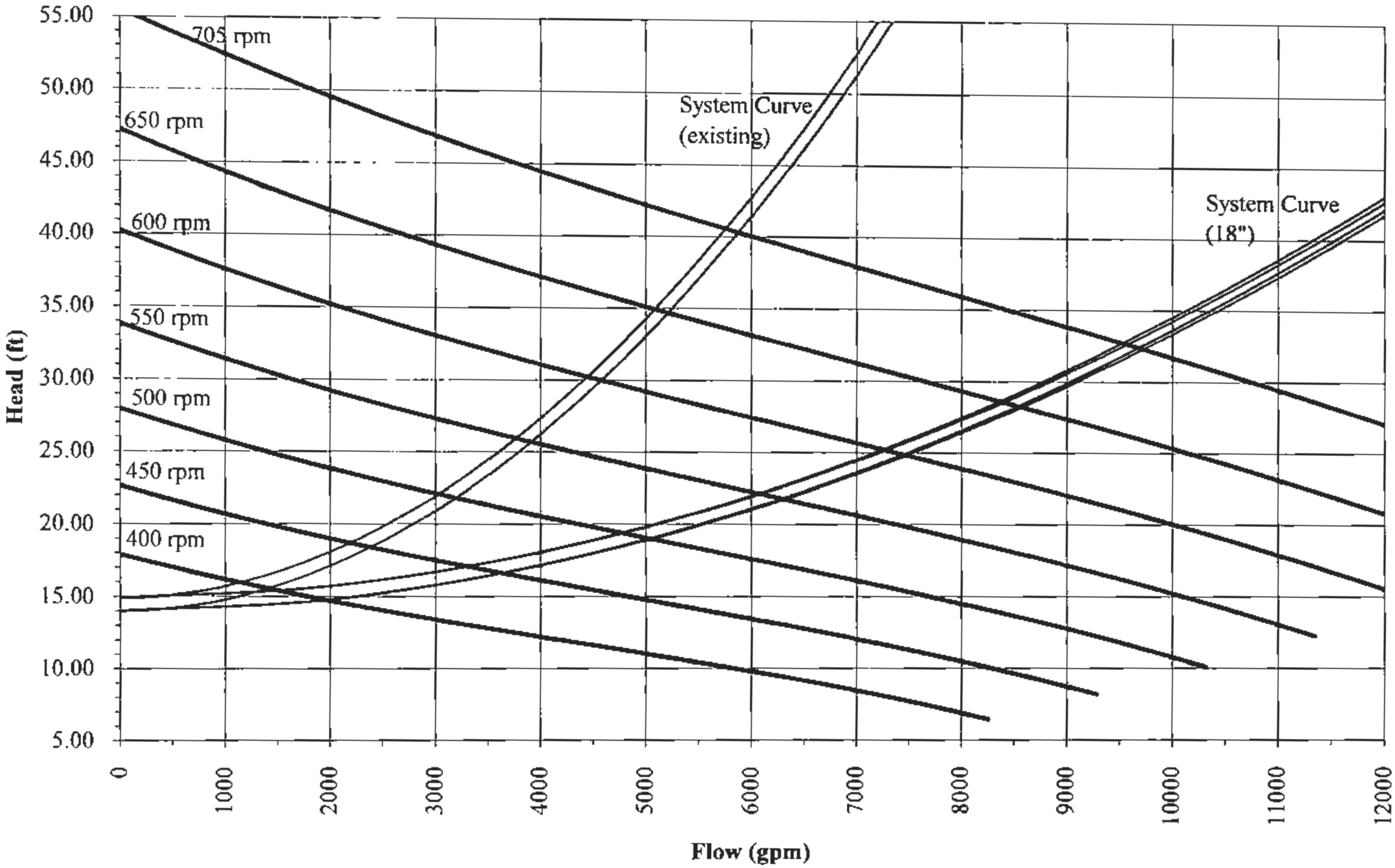


FIGURE 3-8
Alternative 3 Pump and System Curve - Two Pump Operation



4. Recommendations

4.1. Settled Sewage Pumps

The calculated wire-to-water pump efficiency and simple payback for each Alternative is shown in Table 4-1. Detailed wire-to-water calculations can be found in Appendix E.

Table 4-1.
Wire-to-Water Pump Efficiency Summary

Parameter	Existing Pumps[1]	Baseline Condition	Alternative 1	Alternative 2	Alternative 3
Motor (hp)	50	150	50	50	50
Maximum Speed (rpm)	880	880	880	880	705
Pump Efficiency at Average Daily Demand (%)	78.0	82.4	81.5	80.1	82.2
Energy Usage at Average Daily Demand (kW/hr)	25.66	35.44	21.96	22.34	21.77
Energy Usage per Year (kW•hr/yr)	224,793	310,422	192,360	195,722	190,721
Wire-To-Water Efficiency (gal/W/hr)	8.77	6.35	10.25	10.07	10.33
per pump → Future Energy Savings per Year (kW•hr/yr)[2]	NA	0	118,062 x3	114,700 x3	119,701 x ?
Simple Payback (Years)	NA	NA	3.3	1.1 ?	14.3

1 Existing pump calculations based on average daily flow of 5.4 mgd.

2 Future energy savings based on baseline condition at an average daily flow of 6.48 mgd.

Required electrical system modifications are not included in the baseline condition. A cost of $0.10 per kWh, based on the WWTF's most recent electric bill, was used to determine estimated annual energy savings. The cost of each Alternative is as follows:

- Alternative 1: $324,522.
- Alternative 2: $297,378.
- Alternative 3: $455,922.
- Baseline Condition: $285,120.

A simple payback period was calculated by dividing the construction cost differential between each alternative and the baseline condition by the annual energy savings of that alternative.

Replacing the existing pumps and increasing the discharge pipe size results in a clear improvement in wire-to-water efficiency under all three alternatives. At a minimum, the City should benefit with more than a 30 percent reduction in electrical consumption due to the Settled Sewage Pumps. Due to the physical constraints of the pump room coupled with the flow and head requirements, there are a limited number of pump combinations that will provide sufficient redundancy and efficient operation for both low and high flows.

Malcolm Pirnie recommends that the City consider implementing Alternative 2 by replacing the existing Settled Sewage Pumps with three new Patterson F12A pumps. Although this is not the most energy efficient option, the required capital investment is significantly lower and the additional payback for Alternative 3 is negligible. The benefits to Alternative 2 are as follows:

- Less costly than Alternatives 1 and 3.
- Similar or better efficiency than Alternative 1.
- The existing motors and VFDs can be re-used.
- All pump components will be replaced by the improvement, including the shafts (not included in Alternative 1).
- The pumps can be upgraded without performing the piping modifications immediately. The proposed pumps will meet existing flow and head requirements.

The City is currently in the process of replacing the existing Settled Sewage Pumps with three new vertical dry pit non-clog pumps as manufactured by Cornell and has an equipment budget of $100,500. The pumps have not been ordered to date. The equipment cost for the three proposed pumps outlined in Alternative 2 is $73,500. These pumps will also meet the future needs of the City and be able to produce 13.6 mgd with one pump out of service upon completing the piping modifications outlined herein.

At anticipated future average daily flows of approximately 6.48 mgd, the annual electrical demand of the baseline condition would be approximately 310,422 kWh, resulting in an annual cost of approximately $31,042. In comparison, the Alternative 2 pumps, at average daily flows of 6.48 mgd, have an estimated annual electrical cost of $19,236. This results in an annual savings of $11,806.

The baseline condition and Alternative 2 construction costs are approximately $285,120 and $297,378, respectively. The additional construction cost of Alternative 2 is $12,258, not including the additional electrical upgrade costs associated with the baseline condition. Therefore, the simple payback for Alternative 2 is 1.1 years, based on the baseline condition.

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NYSERDA

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Flexible Technical Assistance Program Energy Conservation Study

Appendices

MALCOLM PIRNIE

APPENDIX A

CITY OF KINGSTON, NY ESTIMATED CONSTRUCTION COSTS ALTERNATIVE 1				
DESCRIPTION	**QTY**	**UNITS**	**UNIT COST**	**TOTAL**
ITT-AC 14x14x17.5, 15.125" imp.	3	LS	$32,450	$97,350
Pump Site Labor	1	LS	$19,470	$19,470
Temporary Pumping	1	LS	$50,000	$50,000
Piping Upgrades	1	LS	$103,615	$103,615
			Contingencies (20%):	$54,087
			Total:	**$324,522**

APPENDIX C

CITY OF KINGSTON, NY ESTIMATED CONSTRUCTION COSTS ALTERNATIVE 3				
DESCRIPTION	**QTY**	**UNITS**	**UNIT COST**	**TOTAL**
Patterson F12A, 17.9375" imp. w/ motor	1	LS	$33,000	$33,000
Patterson F16B, 19" imp. w/ motor	2	LS	$55,300	$110,600
75 hp VFD	2	LS	$20,000	$40,000
Pump Site Labor	1	LS	$36,720	$36,720
Temporary Pumping	1	LS	$50,000	$50,000
Piping Upgrades	1	LS	$109,615	$109,615
			Contingencies (20%):	$75,987
			Total:	**$455,922**

APPENDIX D

CITY OF KINGSTON, NY ESTIMATED CONSTRUCTION COSTS BASELINE CONDITION				
DESCRIPTION	**QTY**	**UNITS**	**UNIT COST**	**TOTAL**
Patterson 14x12x21.5 w/ motor & VFD	3	LS	$66,000	$198,000
Pump Site Labor	1	LS	$39,600	$39,600
			Contingencies (20%):	$47,520
			Total:	**$285,120**

APPENDIX E

Wire-To-Water Efficiency Calculations City of Kingston, NY - Settled Sewage Pump								
Manufacturer	Model	Average Daily Flow (gpm)	Average TDH (ft)	Pump Efficiency (%)	Brake Horsepower (HP)	kW/hr	kWh/yr	Wire-to-Water Efficiency (gal/W/hr)
ITT-AC	14x14x17.5	3750	25.5	78.0%	34.40	25.66	224,792.64	8.77
ITT-AC	14x14x17.5 (Alt. 1)	3750	17.5	81.5%	22.59	16.85	147,644.39	13.35
Patterson	F12A (Alt. 2)	3750	17.5	82.3%	22.37	16.69	146,209.21	13.48
Patterson	F12A (Alt. 3)	3750	17.5	84.4%	21.82	16.28	142,571.30	13.82
Patterson	14x12x21.5	3750	25.5	82.9%	32.37	24.14	211,505.74	9.32
ITT-AC	14x14x17.5 (Alt. 1)	4500	19	81.5%	29.44	21.96	192,359.55	10.25
Patterson	F12A (Alt. 2)	4500	19	80.1%	29.95	22.34	195,721.64	10.07
Patterson	F12A (Alt. 3)	4500	19	82.2%	29.18	21.77	190,721.45	10.33
Patterson	14x12x21.5	4500	31	82.4%	47.50	35.44	310,421.82	6.35